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FUEL CONSUMPTION FOR FIELD OPERATIONS

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ABSTRACT

Direct fuel useage was collected from a number of producers for a variety of field operations. The objective being to establish realistic values for comparison purposes.

Cooperators were selected on a wide variety of soil types so that comparisons of soil type, soil moisture content, tillage method, tillage depth, pass number, and combined operations could be compared.

Relative fuel uses also permit identification of use reductions by changing tillage or production techniques.

INTRODUCTION

At present very little reliable direct fuel useage data is available for Ontario crop production operations. Thus an effort was made to collect actual field fuel use information so that more meaningful recommendations can be made to producers on the benefits of: tractor sizing, subsurface drainage, tillage depth, combining of field operations, etc.

METHODOLOGY

The cooperation of seven farmers having soil types varying from sand to heavy clay was obtained. They were given fuel log sheets (see Appendix A) and asked to record fuel useage and any other pertinent information for any field operation that could be clearly identified.

Fuel logs were kept during the (wet) fall harvest of 1986 and the (dry) spring period of 1987.

Larger farm operations were chosen intentionally so that most 'fuel use observations' are from relatively large land areas. This made fuel use recording less onerous for the cooperators because of dedicated tractors for a time period. It also reduced the errors inherent in measuring small quantities of fuel. In addition the larger land area would tend to nullify, for most operations, the fuel used in road travel.

In a few instances gasoline powered tractors and combines were used. Their fuel useage was changed to diesel fuel equivalents (DFE) by multiplying volume by 0.70 which is believed to be a realistic ratio of specific energy utilization for the two fuels.

To date it has not been possible to get accurate fuel use data for silo filling or hay harvesting. Both of these operations as carried on by individual farmers require a number of tractors doing a wide variety of tasks over a short time period. One practical solution would be to solicit the cooperation of custom operators who maintain dedicated units over a longer time period each year.

The other area of concern is the fuel used for 'support services'. For operations such as planting and spraying it is not uncommon to have trucks or wagons moving from field to field carrying seed, fertilizer, water etc. While this increment of fuel useage is likely to be small it is indeed essential to maintain field productivity.

Probably the classic example of 'support services' is the grain buggy transporting grain from a moving combine to the carrier - usually a truck parked at the end of the field or at the farmstead - as was the case in the fall of 1986 when field travel by truck was impossible. By using the grain buggy the field efficiency of combines shelling corn especially can be increased significantly.

No field measurements were made. It was assumed that all of the cooperators being prudent farmers had established realistic estimates of field area. This can often be done by title survey, an acreage meter on planting equipment or a well calibrated field sprayer.

With larger field areas, most being in the 20 to 100 acre range, small area discrepancies are likely to be less important than the effects of irregular shaped small fields - which cause significant overlapping and unproductive backtracking on 'run outs'.

Initially the fuel meters installed by fuel suppliers were not checked for accuracy. It was projected that if an individual cooperator had consistently high or low fuel use data, that meter would be verified before the composite results were printed. However, because of the possibility of minor variations it was also predetermined that no minor variations in specific fuel consumptions between cooperators would be considered significant.

CALCULATIONS

After correction for gasoline powered units all data from the log sheets were transferred to summary sheets for each identifiable operation. The summary sheets were coded by operation and included as Appendix B.

In every case when three or more observations for a specific field operation were available an average DFE value in litres per acre (L/A) and in litres per hectare (L/ha) was calculated.

Figure 1 was prepared using average fuel use data for various field operations. The intent was to provide a mechanism to permit quick comparison of the relative quantities of fuel used for the major segments of the crop production sequence.

Table I was prepared to permit comparison of the typical fuel useage for grain corn, soybeans and winter wheat employing conventional tillage. A range is inevitable due to varying production techniques, but more importantly the use areas are identified in a relative way such that the opportunity for fuel use reduction using minimum or zero tillage can be identified.

Table II was prepared to permit average field fuel uses to be compared to values from other sources. In particular the effects of No-till on planting and harvesting fuel use requirements was considered useful.

OBSERVATIONS

From Figure 1 it is evident that primary tillage is the largest single user of direct fuel energy. It is however interesting to note the wide variation (range) of fuel use for primary tillage operations.

For moldboard plowing, cooperator #1 had specific fuel consumptions varying from a low of 20.8 to a high of 25.9 L/ha. The lowest consumption occured on sandy loam while the higher consumptions occured on wet clay which was slippery and on fields containing eroded clay knolls which would have low organic matter and high shear resistance.

Cooperator #2 recorded an even wider range of specific fuel consumptions when moldboard plowing. The lowest was 11.1 L/ha when plowing mellow ground containing red clover after wheat. The highest was 25.3 L/ha when plowing semi frozen ground having a slippery surface after compaction by the combine during the wet fall corn harvest of 1986. It is worth noting that the perceived plowing depth of 130 mm was maintained.

Unfortunately only limited fuel use data was obtained for fall tillage by chisel plows or coulter-chisel plows. It would appear from the data that if one pass is adequate fuel savings are possible. The second pass, while requiring less fuel, will put the total consumption over that likely required for moldboard plowing.

The use of the chisel plow was limited in the fall of 1986 due to wet soil conditions. Dry soil to encourage soil shattering, as opposed to smearing, is considered a desirable prerequisite for chisel plow effectiveness (Vyn et al, 1979).

Secondary Tillage:

While some cooperators, especially those working lighter soils, used a tandem disc most secondary tillage was done with S-tine cultivators with rolling harrows attached.

Significant variation in specific fuel consumption with the S-tine cultivator did occur from the overall average of 5.43 L/ha from 42 observations. The first pass over plowed or unplowed soil tended to have the higher fuel use rates, with the 2nd and 3rd passes requiring less. This is not unrealistic as the first pass is usually done at slower than desired speed because of the rough surface (and rough ride) and crusted surface which requires shattering to a greater depth for levelling.

While decreased fuel consumption with successive passes is common, one must not lose sight of the cumulative fuel consumption required. This is best illustrated in Table I.

The fuel use data from cooperator #6 shows the effect of cultivation depth. Even on sand the fuel consumption is much higher when the S-tine cultivator is set deep, 130 to 150 mm, as compared to 100 mm or less.

Cooperator #5 used the S-tine cultivator to incorporate herbicides on two occasions while the tractor carried the spray tanks. It is interesting to note an increased fuel consumption, for that later pass, that almost equals the fuel consumption for a separate spray pass.

The varied soil types covered by cooperator #1 does indicate some reduction in fuel consumption based on soil type for the same pass (e.g. #1) but the results are not consistent enough to show significant differences.

Harrowing, using diamond harrows, is a relatively small user of fuel at 1.57 L/ha. The major portion of that fuel would be required just to run the tractor over a loose seedbed. Harrowing, is however still practiced to level tilled soil or cover seeds after drilling.

Fertilizing and Spraying:

Applying anhydrous ammonia with conventional knife teeth on a toolbar is a relatively high energy use averaging 6.82 L/ha.

In contrast spreading dry fertilizer with the conventional four tonne spinner spreader travelling at 12 m intervals requires only 1.98 L/ha per pass. In all observations this fuel consumption included trips to the local fertilizer depot to acquire spreaders and/or materials.

Field spraying is also a relatively small user of direct energy with an average use of 1.72 L/ha. With wide boom sprayers, ranging from 8.5 to 11.6 m in this survey, the travel distance per hectare or acre is relatively small. For cooperator #3 with relatively low fuel consumption values (1.49 and 1.39 L/ha) the consumption included travelling at least one kilometre for refills and tractor operation during sprayer cleaning.

Cooperator #5 employed a larger than essential tractor for field spraying because of the dual nature of his spraying system. The tractor mounted tanks and pump provided spray to a boom on the cultivator or to a 3 ph boom used for conventional field spraying. As a result of those high values, 2.76 and 2.00 L/ha, the average is moved upward significantly. The other four observations would have an average of 1.40 L/ha as compared to the 1.72 L/ha reported.

Planting and Drilling:

The data given in sections B and C of Appendix B are for the fuel used in the planting/drilling tractor only. No allowance (or measurement) was made for the vital support services. During planting one or two support units are often employed to supply seed and fertilizer. The fuel use is likely small and could be accounted for by adding about 10% to the planting fuel use.

The 11 corn planting observations yield an average fuel use of 2.91 L/ha with a range from 2.16 to 3.74 L/ha.

The cooperator #3 data shows a slight reduction in fuel useage when the fertilizer application rate was reduced by 20%. This reduction would be accounted for by less travel time to the fertilizer dispensing unit.

The data from cooperator #5 would indicate some, but not a significant increase in fuel useage when planting no-till into a sandy soil. It is predicted that no-till into a clay/clay loam soil could increase the fuel consumption - especially with ridges when trash removers are required and more weight might be added. However, when any increase even to 100% is compared to tillage fuel useage the benefits would be positive.

The corn planting data from cooperator #1 is highly variable but reflects the influence of a number of factors. For normal planting (OBS. #6 and 10) the fuel consumption rates 2.84 and 2.62 are consistent with cooperator #3 data. However, when the planting tractor carried spray solution for banding on soft tilled soil the fuel consumption rate increased significantly. The average fuel consumption for observations 7, 8 and 9 is 3.49 L/ha an average increase of 0.76 L/ha or 28%.

Fuel use in observation #11 was increased by a soft (deep) seedbed requiring dry soil to be moved aside to permit planting to moisture at 50 mm without excessive seed cover. The field contained knolls which further increased fuel consumption when the tractor was climbing on an unfirm soil surface.

Most of the cooperators planting soybeans used newer model grain drills to plant 'solid' in 180 mm rows. The average fuel use rate from 12 observations is 3.03 L/ha. While this is only slightly higher than the rate for planting corn it does reflect the narrower row spacing and increased number of disc opener units being pulled through the soil. The seeding rate per hectare is also higher than for corn, and with large seed carrying capability the drilling unit is as heavy as a corn planter loaded with fertilizer.

Cooperator #5 used slightly more fuel than cooperator #3 because he used a narrower drill which would require more field travel. By comparison cooperator #1 with the same size of drill as cooperator #3 used more fuel but combined a spraying operation. The increased fuel use rate is likely to have resulted from the loaded spray tanks being carried on the planting tractor.

Cooperator #7 had the highest fuel use rate but he planted the beans with a relatively heavy planter and combined a spraying operation as well.

Summary sheet M-1 lists individual observations for drilling winter wheat and peas. As would be expected the shallow drilling of wheat used less fuel than the deeper drilling depth required for peas. In addition the peas were drilled at 247 Kg/ha, requiring more stops/trips for refilling, than for wheat which was drilled at half that rate. (For comparison soybeans were drilled at about 90 Kg/ha.)

Row - Cultivating:

Row cultivating is often employed to break crust, hill the crop and/or control weed escapes. The average fuel use rate for eight observations is 2.12 L/ha. While it is a slightly higher direct user of fuel than field spraying the indirect energy and dollar costs of herbicides are not required.

Two inter-row cultivations often occur which would double the reported fuel use rate.

Combine Harvesting:

Combining crops in the field is a relatively high energy use operation. The relatively heavy combine is required to cut/pick, thresh/shell, separate, clean and carry the harvested grain or oilseed.

The highest fuel use rate was for grain corn, averaging 17.7 L/ha, which reflects the higher power requirement of the picking head as well as the large volume of grain per hectare that must be carried.

The fuel use range for the eight observations is relatively small considering the variation in size of combines covered. The other very interesting observation is the minimal effect on combine fuel consumption of grain buggy support. This should not be used as a criterion to discourage the use of grain buggies to move corn, or other crops, from the combine. There is no doubt that the field efficiency of the expensive combine can be increased significantly, probably 20 or 30% in many cases, by keeping it doing the job it was designed to do and using grain buggy support.

The fuel use of the tractor on the grain buggy, the grain buggy fixed costs and the additional operator can easily be justified when compared to the alternative - that is purchasing and operating a second combine to cover a large acreage.

Combining soybeans or winter wheat requires less fuel than combining corn. Most combines cover a wider swath with soybeans or wheat at similar forward speeds. In addition the volume of grain/oilseeds per hectare that must be carried is lower.

The average of five soybean combining observations is 11.4 L/ha while the one observation for wheat is lower at 9.40 L/ha.

The soybean harvesting results highlight the benefits of good land drainage. When combining corn the combine can often be carried by the corn root system which provides some floatation capability. That phenomenon does not carry through to a soybean field. When the soil is excessively wet, as it was in the fall of 1986, the combine cuts ruts in saturated soil.

For cooperator #3 the fuel consumption increased by 50% when the combine moved from a systematically drained to a randomly drained field of the same soil type. Cooperator #1 results indicted an increase of almost 30% for similar circumstances.

The increased fuel consumption, while important, becomes secondary to the increased stresses on the drive train of the combine (and the operator) when working in muddy field conditions. In addition the field efficiency of the combine is also reduced.

It is conceivable that the average fuel consumption rates obtained for harvesting both corn and soybeans in 1986 are higher than the long term average values. The one fuel use figure for winter wheat, obtained during dry conditions in July of 1987 might be close to a realistic long term value for soybeans.

One attempt was made to obtain fuel use data for harvesting whole-plant, corn silage in the fall of 1986. See page N-1 in Appendix B. It was totally frustrated by extremely muddy conditions and harvest delays due to rain even on systematically tiled land.

CONCLUSIONS

The direct use of fuel energy to produce and harvest common Ontario field crops is a relatively small cost component of the total input cost when all inputs including machinery fixed costs and fertilizer and pesticide costs are included. Reductions are however possible and worthwhile.

Table I highlights direct field fuel useage for three crops with conventional tillage practices. The ranges shown indicate some flexibility which is likely to occur from year to year depending on preceeding crop, weather, weed escapes and other factors.

In many instances producers are interested in reducing tillage passes whenever possible. The main objective is not necessarily to save direct fuel energy but to reduce the time and labour required during the busy and stressful planting season. Most of the effort is and should be directed to saving fuel in the primary and seed bed preparation phases. For corn and soybeans a high percentage of the fuel is used in these phases.

Fuel use for harvesting offers little opportunity for reduction with the exception of having well drained soil to minimize rutting. The need for excessive transport distances by combine to trucks or wagons located on firm soil could also be minimized to increase field efficiency.

Carrying extra weight on the tractor when planting on a soft seedbed does indeed increase fuel consumption rate. When practical dualling the wheels of the planting tractor, or removal of tire ballast is likely to show very positive results while reducing soil compaction.

With the exception of one field spraying equipment combination all cooperators appeared to be using well matched tractor sizes for the field operations. This factor tended to aid greatly in providing consistent results.

Tillage depth appears to be more critical than soil type in fuel utilization. Tillage depth should be kept to a minimum consistent with preparing a suitable and level seedbed. In order to use wide planting equipment and maintain uniform planting depth a level seedbed is essential.

Rolling land, and especially eroded clay knolls, increases energy use. These are land areas that should be strip cropped across the slope, rotated in grass to increase organic matter, or be designated for other uses as they are not usually highly productive land areas. Unfortunately many of these areas are small and do not lend themselves to special treatment just to save fuel energy.

When practical field operations should be combined to minimize trips across the field. This is especially true with secondary tillage operations. The cultivating tractor can easily pull rolling/smoothing harrows to 'fine' a seedbed eliminating a second tractor pass. For light draft equipment, such as harrows operated at narrow intervals the major fuel usage is attributable to moving the tractor on loose soil. However, for wider equipment such as a boom type field sprayer, the fuel useage is not significantly greater than the increased fuel required by a planting tractor to carry the spray tanks when applying herbicides to a narrower swath - the width of the planting equipment. Similarly there is not likely to be a significant fuel use advantage in applying herbicides directly in front of an incorporating cultivator. However, some herbicides must be incorporated within minutes of application. The combined spraying-cultivation pass does eliminate a second tractor operator in this case but usually requires a mobile support vehicle to provide water and spray materials.

Comparisons with other data:

The results of this field energy use survey are reasonably consistent with the plot results obtained by Young and Baldwin (1986) at Ridgetown. They tended to strive for minimum tillage with only one seedbed preparation pass which is not consistent with common field practice especially where herbicides are incorporated or seedbed levelling in larger areas is required.

The data from Lobb (1986) and Michigan (1981), see Table II, show some interesting comparisons. Lobb's field fuel energy to moldboard plow is significantly lower than the survey average. This reduction may be due to the silty clay/clay loam soil in Huron County having a low shear resistance.

In contrast Lobb's corn planting fuel useage is much higher on conventional tillage (C-T) with a slight increase showing for planting no-till (N-T) which would be anticipated. His high C-T planting value is consistent with the Michigan data and this leads one to speculate that planting is often done out with an oversized, overballasted or poorly tuned tractor. No values from the survey data exceeded 3 L/ha except for one no-till observation and three observations when the tractor carried spray tanks (overballasted) and one where the planting tractor was operated on a rolling and soft seedbed.

Based on Lobb's data for no-till corn planting, the Michigan increase shown of 33% appears to be unwarranted. His increase is only 9% and is probably a more realistic increase. The increase is likely to vary with the amount of in row tillage done by the planter and the amount of fertilizer, sprays or other weight carried by the planter or tractor.

The field spraying data average from Michigan appears to be unrealistically high - 80% above the survey average. As noted previously the survey data is even biased high by two of the six observations.

Row cultivation also shows significant fuel use differences among the three data sources. Again the results of the survey are believed to be consistent and realistic - while being the lowest.

Fuel use data for combining corn and soybeans offer no major discrepancies. The wet ground conditions in the fall of 1986 would tend to increase the survey results for both corn and soybeans. It is however interesting to note a slight fuel use reduction when the Lobb combine operated on the firmer ground surface provided by no-till.

Further data collection:

The survey results reported will be of value as they cover a range of soil types and conventional tillage practices. They do not however, permit definitive statements to be made about the effect of tillage depth, tillage pass number, wheel slippage and other fuel use factors. The only way that this can be accomplished would be to fully instrument one tactor and use it over the desired range of conditions. This action would eliminate the outside variables inherent in a field survey involving different tractors and operators.

Agriculture Canada staff at Ottawa are in the process of instrumenting a 110 kW tractor with front wheel assist for testing/demonstration purposes. It is conceivable that the O.M.A.F. Agricultural Energy staff will be able to cooperate in the collection of more specific fuel comsumption data in Ontario - probably in 1989.

SUMMARY

All cooperators in the survey group were using field fuel energy effectively. While some minor adjustments may be possible, the additional capital and labor cost would often more than override potential fuel energy savings with the present net price of diesel fuel at $0.25/L.

The only significant reductions in fuel useage would have to come from reduced primary or secondary tillage. That is a change from conventional to minimum or even no-till. That degree of management change must be induced by benefits other than saving direct use fuel energy. Reductions in fixed capital (machinery) costs per hectare while maintaining yield levels will be the only incentive.

Research work and demonstration projects on reduced tillage should be continued. Soil type, fertilizer placement, weed control, soil erosion etc. are all factors that must be considered in any programs that will encourage reduced tillage.

Land drainage is another concern in reducing both direct and indirect field energy use. Harvesting crops from wet soils requires more fuel energy, reduces field efficiency (ha/h) and increases machinery maintenance. The last two are likely to cost the producer more dollars than the increase in direct fuel useage.

The direct fuel use to move harvested grain a nominal distance of 10 Km to a local elevator can be from 1.6 L/ha for soybeans to 6.4 L/ha for wet corn. These values are not high but must be added to a producer's cost of production.

If and when diesel fuel costs rises significantly the impact will be felt as an increased production cost. It is therefore prudent that every primary food producer in Ontario evaluate his/her direct field energy uses and attempt, where practical, to moderate those uses consistent with maintaining productivity.

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A special thanks to Don Lobb of Clinton, Ontario who permitted his fuel use data to be used prior to publication. His data in Table II permits some useful comparisons of the effect of No-Till on specific fuel uses.

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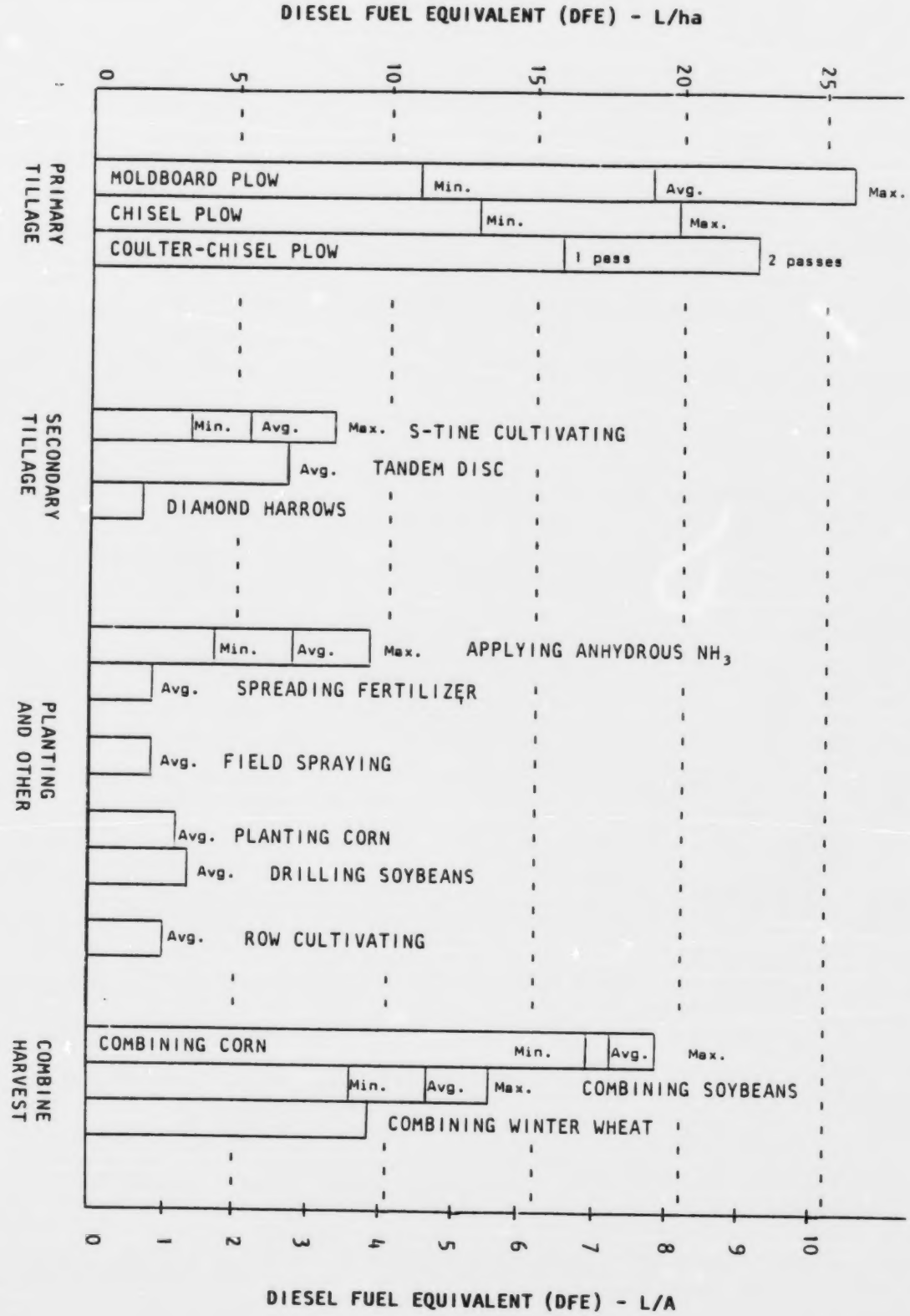

Fig. 1 Relative fuel use for various field operations.

TABLE I

TYPICAL FIELD FUEL USE FOR VARIOUS CROPS
WITH CONVENTIONAL TILLAGE*

Field Operation	Min**/Max	DFE - L/ha Grain Corn	Soybeans	Winter Wheat
Primary tillage		19.2	19.2	---
Seed bed preparation	2x	10.86	10.86	10.86
	4x	21.72	21.72	---
Spread Fertilizer	1x	1.98	1.98	1.98
	2x	-----	-----	3.96
Plant/Drill		2.91	3.03	1.97
Apply Anhydrous		6.82	----	----
Spray	1x	1.72	1.72	1.72
	2x	3.44	3.44	----
Row Cultivate	1x	2.12	2.12	----
	2x	4.24	----	----
Harvest		17.7	11.4	9.40
MINIMUM L/ha		63.3	48.2	25.9
MAXIMUM L/ha		78.0	62.9	27.9
MINIMUM L/A		25.6	19.5	10.5
MAXIMUM L/A		31.6	25.5	11.3

* The number of field passes for various operations can vary significantly depending on soil condition, herbicide application technique and weed escapes.

** Minimum and Maximum number of passes when in excess of one.

TABLE II

FIELD FUEL USE AVERAGES FROM DIFFERENT SOURCES
FOR COMPARISON

Field Operation		Avg. Survey Data	DFE - L/ha Lobb Data **	Michigan Data ***
Primary Tillage				
Moldboard Plow		19.2	14.0	16.9
- with packer (sand)		18.0*	----	----
Chisel Plow		16.6*	----	12.7
Coulter-Chisel Plow	1x	15.9*	----	----
	2x	22.2*	----	----
S-Tine Cultivator		5.25*	6.18	----
Secondary Tillage				
S-Tine Cultivator		5.43	4.20	7.30
Tandem Disc		6.34	5.76	8.70
Diamond Harrows		1.57*	----	----
Applying Fertilizer				
Knifing Anhydrous		6.82	----	5.43
Sidedressing Liquid N		----	3.36	----
Bulk Spreading		1.98	1.11	2.81
Field Spraying				
Boom Sprayer @ 225 L/ha		1.72	2.03	3.09
Planting				
Planting Corn	C-T	2.91	4.37	4.77
	N-T	----	4.76	6.36
Drilling Soybeans		3.03	----	5.24
Drilling Wheat		1.97*	----	----
Drilling Peas		2.57*	----	----
Row Cultivating				
Four/Six Row		2.12	3.58	3.65
Combining				
Corn	C-T	17.7	14.2	14.1
	N-T	----	12.1	----
Soybeans	C-T	11.4	9.76	11.5
	N-T	----	9.02	----
Wheat		9.40	----	11.5

C-T Following conventional tillage
N-T No tillage prior to planting

* Values from survey data with fewer than three observations averaged.

** Values obtained from Don Lobb data collected in 1986 near Clinton Ontario on Silty Clay-Clay Loam soil.

*** Average Michigan data from a farm energy audit as published in Energy Facts, Ext. Bulletin E-1535, MSU, July 1981, 'Fuel Requirements for Field Operations'. (US gal/A converted to L/ha by multiplying by 9.36)

FUEL LOG - TRACTORS AND S.P. EQUIPMENT

OMAF - AGRICULTURAL ENERGY CENTRE

Year 19..... Cooperator .....

DATE	OPERATION	FUEL USED Gasoline/Diesel Litres/Gallons	Acres/ha Covered	Soil Type	Soil Moist.	COMMENTS e.g. Depth, Pass No., etc.	

RGW/10/86

APPENDIX 'A'

APPENDIX 'B'

CODING OF FIELD USE - DATA SUMMARY SHEETS

Page Prefix		Field Operation
A	-	S-Tine Cultivating
B	-	Planting Corn
C	-	Drilling Soybeans
D	-	Field Spraying
E	-	Applying Anhydrous Ammonia
F	-	Spreading Dry Fertilizer
G	-	Row Cultivating
H	-	Moldboard Plowing
I	-	Other Primary Tillage
J	-	Other Secondary Tillage
K	-	Combining Corn
L	-	Combining Soybeans/Winter Wheat
M	-	Miscellaneous Operations
N	-	Silo Filling - Corn

A-1

FIELD FUEL USE - DATA SUMMARY

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
1	6	S-TINE CULTIVATING	Sand	Dry	18	56.8	3.15	7.79	- 3.2 m cultivator - 130 to 150 mm deep
2	6	S-TINE CULTIVATING	Clay Loam	"	36	65.9	1.83	4.52	- 3.2 m cultivator - 100 mm deep
3	6	S-TINE CULTIVATING	Sand	"	18	38.6	2.14	5.30	"
4	5	S-TINE CULTIVATING	Clay Loam	"	15	30.2	2.01	4.97	- 6 m cultivator - 75 mm deep - 1st pass/fall plowed
5	5	S-TINE CULTIVATING	"	"	17	35.6	2.09	5.17	- 100 m - secondary pass
6	5	S-TINE CULTIVATING	Sand to Clay Loam	"	63	150	2.38	5.88	- 75 to 100 mm deep - secondary pass
7	5	S-TINE CULTIVATING	Sand	"	48	81.0	1.69	4.17	- 50 to 75 mm deep - secondary pass on disked ground
8	5	S-Tine CULTIVATING plus spraying	Clay Loam	"	25	65.6	2.62	6.48	- 100 mm deep - 19 Km road travel - ppi
9	5	S-TINE CULTIVATING	Mixed c/w Clay Hill	"	17	50.3	2.96	7.31	- 100 mm deep - 2x on plow finishes
10	5	S-TINE CULTIVATING plus spraying	Clay Loam	"	17	42.1	2.48	6.12	- 100 mm deep - ppi
11	5	S-TINE CULTIVATING	Clay Loam	"	21	56.8	2.70	6.68	- 100 mm deep - 1st pass/fall plowed

FIELD FUEL USE - DATA SUMMARY

A-2

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
12	4	S-TINE CULTIVATING	Sandy Loam	Dry	28	59	2.11	5.20	- 6 m cultivator c/w rolling harrows - 1st pass/fall plowed - tiled previous summer
13	4	S-TINE CULTIVATING	Clay Loam	"	42	105	2.50	6.18	- 28 acres 2nd pass - 14 acres 1st pass/bean stubble - 130 mm deep
14	4	S-TINE CULTIVATING	Sandy Loam	"	28	50	1.78	4.41	- 3rd pass - 100 mm deep
15	4	S-TINE CULTIVATING	Clay Loam	"	18	45.5	2.53	6.24	- 1st pass unplowed bean stubble - 100 to 130mm deep(6-8Kmh)
16	4	S-TINE CULTIVATING	Clay Loam	"	16	40.9	2.56	6.31	- 2nd pass - 100 mm deep (8Kmh)
17	4	S-TINE CULTIVATING	Clay Loam	"	18	40.9	2.27	5.61	- 2nd pass - 130 mm deep
18	4	S-TINE CULTIVATING	Clay Loam	"	40	72.7	1.82	4.49	- 20 acres - 3rd pass - 20 acres - 2nd pass - 100 mm deep
19	4	S-TINE CULTIVATING	Clay Loam	"	62	118	1.90	4.70	- 30 acres - 3rd pass - 32 acres - 1st pass - fall plowed
20	4	S-TINE CULTIVATING	Clay Loam	"	160	373	2.33	5.76	- 109 acres - 1st pass/ fall plowed - 51 acres - 2nd/3rd pass - 100 mm deep
21	4	S-TINE CULTIVATING	Clay Loam	"	80	173	2.16	5.34	- 3rd pass - 100 mm deep
22	4	S-TINE CULTIVATING	Clay Loam	"	70	118	1.74	4.29	- 3rd pass (long rounds) - 100 mm deep (or less)

FIELD FUEL USE - DATA SUMMARY

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
23	1	S-TINE CULTIVATING	Loam	Moist	110	304	2.76	6.83	- 8.5 m cultivator c/w rolling harrows - 1st pass
24	1	S-TINE CULTIVATING	Loam	"	103	286	2.78	6.86	"
25	1	S-TINE CULTIVATING	Loam	"	65	161	2.48	6.12	"
26	1	S-TINE CULTIVATING	Sandy Loam	"	57	112	1.96	4.85	"
27	1	S-TINE CULTIVATING	Clay Loam	Dry	120	222	1.85	4.57	- 2nd pass
28	1	S-TINE CULTIVATING	Clay Loam	"	120	193	1.61	3.97	- 3rd pass
29	1	S-TINE CULTIVATING	Sandy Loam	"	100	204	2.04	5.04	- 2nd pass
30	1	S-TINE CULTIVATING	Sandy Loam	Moist	65	124	1.91	4.71	- 1st pass
31	1	S-TINE CULTIVATING	Clay to Sandy Loam	Moist	90	137	1.52	3.76	- 1st pass
32	1	S-TINE CULTIVATING	Clay to Sandy Loam	"	130	231	1.78	4.39	- 2nd pass
33	1	S-TINE CULTIVATING	Clay Loam	"	85	168	1.98	4.88	- 1st pass
34	1	S-TINE CULTIVATING	Clay Loam	"	80	157	1.96	4.85	- 2nd pass

FIELD FUEL USE - DATA SUMMARY

A-4

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
35	1	S-TINE CULTIVATING	Clay	Dry	90	174	1.93	4.77	- 2nd pass
36	1	S-TINE CULTIVATING	Clay	"	56	158	2.82	6.97	- 3rd pass - shallow
37	1	S-TINE CULTIVATING	Clay Loam	Moist	40	122	3.05	7.53	- 1st pass - deeper than normal
38	1	S-TINE CULTIVATING	Clay Loam	Dry	84	201	2.39	5.91	- 1st pass
39	1	S-TINE CULTIVATING	Clay Loam	"	110	220	2.00	4.94	- 3rd pass - hard ground
40	1	S-TINE CULTIVATING	Loam	"	107	214	2.00	4.94	- 3rd pass
41	1	S-TINE CULTIVATING	Sandy Loam	"	60	100	1.67	4.12	- 2nd and 3rd pass - for ppi
42	7	S-TINE CULTIVATING	Clay	Moist	70	147	2.10	5.19	- 1st and 2nd pass - 6.7 m cultivator - 75 mm deep
			AVERAGE OF	42 OBSERVATIONS			2.20	5.43	

B-1

FIELD FUEL USE - DATA SUMMARY

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
1	3	PLANTING CORN	Clay Loam	Dry	28	28.6	1.02	2.53	- 4 row wide - applying fertilizer
2	3	PLANTING CORN	"	"	16.5	17.2	1.04	2.57	"
3	3	PLANTING CORN	"	"	32	28.0	0.875	2.16	- 4 row wide - less fertilizer - square field (long rounds)
4	3	PLANTING CORN	"	"	32	30.9	0.96	2.38	- 4 row wide - many turns
5	5	PLANTING CORN	Sand & Sandy loam	"	48	60.5	1.26	3.11	- 4 row wide - 38 acres no-till
6	1	PLANTING CORN	Loam	"	47	54	1.15	2.84	- 6 row narrow - applying fertilizer
7	1	PLANTING CORN	"	"	59	86	1.46	3.60	- 15 acres band sprayed - saddle tanks half full - many short rounds
8	1	PLANTING CORN	"	"	75	95	1.27	3.13	- banding herbicide - saddle tanks on tractor
9	1	PLANTING CORN	"	"	82	124	1.51	3.74	"
10	1	PLANTING CORN	Clay Loam	"	65	69	1.06	2.62	- no herbicide banding
11	1	PLANTING CORN	Clay	"	36	49	1.36	3.36	- rolling land - soft seedbed(NH_3 preplant) - 50 mm soil moved aside
									- planting 50 mm deep
			AVERAGE OF	11 OBSERVATIONS			1.18	2.91	

FIELD FUEL USE - DATA SUMMARY

C-1

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
1	5	DRILLING SOYBEANS	Mixed	Dry	38	45.0	1.18	2.92	- 16 x 7 drill - 38 mm deep
2	3	DRILLING SOYBEANS	Clay Loam	"	30	32.5	1.08	2.67	- 38 mm deep - many turns
3	3	DRILLING SOYBEANS	Clay Loam	"	13.5	12.7	0.94	2.33	- 38 mm deep - long rounds
4	3	DRILLING SOYBEANS	Clay Loam	"	68	57.3	0.84	2.08	- 38 mm deep - mostly long rounds
5	1	DRILLING SOYBEANS	Clay Loam	"	56	78	1.39	3.44	- 21 x 7 drill - spraying preemerge - saddle tanks on tractor
6	1	DRILLING SOYBEANS	Clay Loam	"	80	108	1.35	3.33	"
7	1	DRILLING SOYBEANS	Clay Loam	"	52	65	1.25	3.09	"
8	1	DRILLING SOYBEANS	Loam	"	50	63	1.26	3.11	"
9	1	DRILLING SOYBEANS	Loam	"	65	86	1.32	3.27	"
10	1	DRILLING SOYBEANS	Clay Loam	"	45	54	1.20	2.96	"
11	1	DRILLING SOYBEANS	Sandy Loam	"	29	40	1.38	3.41	"
12	7	PLANTING SOYBEANS	Clay	"	35	53	1.51	3.74	- 12 x 450 mm row planter - spraying preemerge
			AVERAGE	OF 12	OBSERVATIONS		1.23	3.03	

FIELD FUEL USE - DATA SUMMARY

D-1

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
1	3	SPRAYING	Clay Loam	Dry	111.5	67.1	0.60	1.49	- trail sprayer (1900L) - preemerge on soybeans - 20 GPA - 10.7m boom
2	3	SPRAYING	"	"	80.5	45.2	0.56	1.39	- post emerge on corn - 20 GPA
3	5	SPRAYING	Sand & Sandy Loam	"	48	53.7	1.12	2.76	- tractor mounted sprayer - large tractor-11.6m boom - preemerge on corn
4	5	SPRAYING	---	Dry	198	160.6	0.81	2.00	- post emerge on wheat and corn
5	6	SPRAYING	---	"	18	9.1	0.51	1.25	- small trail sprayer - on corn - 8.5 m boom
6	1	SPRAYING	Loam	"	70	41	0.59	1.45	- trail sprayer (1900L) - 8.5 m boom - post emerge on corn
			AVERAGE OF 6 OBSERVATIONS				0.70	1.72	

FIELD FUEL USE - DATA SUMMARY

E-1

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
1	5	APPLYING ANHYDROUS NH_3	Primarily Sandy Loam	Dry	90	267.9	2.98	7.35	- 5 tooth applicator - 130 mm deep - side dressing-970 mm rows
2	1	APPLYING ANHYDROUS NH_3	Loam	"	63	211	3.34	8.27	- 7.6 m - preplant - 160 mm deep - small fields
3	1	APPLYING ANHYDROUS NH_3	Loam	"	49	141	2.88	7.11	- 7.6 m - preplant - 160 mm deep
4	1	APPLYING ANHYDROUS NH_3	Sandy Loam	"	75	194	2.59	6.39	"
5	1	APPLYING ANHYDROUS NH_3	Clay	"	35	130	3.71	9.17	" - rolling land with hard clay knolls
6	1	APPLYING ANHYDROUS NH_3	Loam	"	78	128	1.64	4.05	- side dressing - 760 mm rows
7	1	APPLYING ANHYDROUS NH_3	Loam	"	60	132	2.20	5.43	"
			AVERAGE OF 7 OBSERVATIONS				2.76	6.82	

FIELD FUEL USE - DATA SUMMARY

F-1

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
1	4	SPREADING FERTILIZER	Clay Loam	Dry	90	68	0.75	1.87	- 4t spinner spreader - includes trips for material - in spring
2	1	SPREADING FERTILIZER	Clay Loam	Moist	60	45	0.75	1.85	- as above - in fall - hauled seed wheat
3	1	SPREADING FERTILIZER	Clay Loam	"	100	90	0.90	2.22	- including travel - ground soft to slippery
			AVERAGE OF	3 OBSERVATIONS			0.80	1.98	
	5	SPREADING SOLID MANURE	Clay Loam	Dry	17	78.9	4.64	11.46	- not including loading - 1.2 km haul - 4.5 t/A

FIELD FUEL USE - DATA SUMMARY

G-1

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
1	3	ROW-CULTIVATING (CORN)	Sandy Loam	Dry	44.5	49.3	1.11	2.74	- 4 row wide - slow due to quack grass
2	1	ROW-CULTIVATING (CORN)	Loam	"	43	36	0.84	2.07	- 6 row narrow - higher gear-low rpm
3	1	ROW-CULTIVATING (CORN)	Loam	"	50	40	0.80	1.98	"
4	1	ROW-CULTIVATING (CORN)	Loam	"	82	64	0.78	1.93	"
5	1	ROW-CULTIVATING (CORN)	Loam	"	78	65	0.83	2.06	"
6	1	ROW-CULTIVATING (CORN)	Loam	"	50	35	0.70	1.73	"
7	1	ROW-CULTIVATING (CORN)	Loam	"	50	42	0.84	2.07	"
8	7	ROW-CULTIVATING (SOYBEANS)	Clay	"	35	34	0.97	2.40	- 12 rows @ 450 mm
			AVERAGE OF 8 OBSERVATIONS				0.86	2.12	

FIELD FUEL USE - DATA SUMMARY

H-1

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	SPEC. FUEL CONS. L/ha	COMMENTS
1	4	MOLDBOARD-PLOWING	Clay Loam	Wet	20	122.7	6.14	15.2	- Wet fall conditions - Rutted corn stubble - 5 x 400 mm plow - 150 mm
2	4	MOLDBOARD-PLOWING	Clay Loam	Wet No Mud	68	523	7.69	19.0	- corn stalks - 180 mm deep
3	1	MOLDBOARD-PLOWING	Clay	Wet	83	804	9.69	23.9	- 6 x 460 mm - 180 mm deep - slippery surface - corn stalks
4	1	MOLDBOARD PLOWING	Sandy Loam	Moist	55	463	8.42	20.8	- 180 mm deep - corn stalks
5	1	MOLDBOARD-PLOWING	Clay Loam	Moist	90	942	10.5	25.9	- hard plowing - clay knolls - corn stalks
6	1	MOLDBOARD-PLOWING	Clay Loam	"	82	703	8.57	21.2	- corn stalks
7	1	MOLDBOARD-PLOWING	Clay Loam	"	58	538	9.28	22.9	- hard plowing - slightly frozen ground surface
8	2	MOLDBOARD-PLOWING	Loam	Wet No Mud	85	382.2	4.50	11.1	- 9 x 460 mm - 130 mm deep - red clover/wheat stubble - 9 Kmh
9	2	MOLDBOARD-PLOWING	Loam	"	70	364	5.20	12.9	- corn stalks - 9.6 Kmh
10	2	MOLDBOARD-PLOWING	Loam	"	100	546	5.46	13.5	- corn stalks - 9.6 Kmh
11	2	MOLDBOARD-PLOWING	Loam	"	40	409.5	10.24	25.3	- corn stalks - not over 130 mm deep - ground partly frozen
			AVERAGE OF 11 OBSERVATIONS				7.79	19.2	

FIELD FUEL USE - DATA SUMMARY

H-2

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
1987	4	MOLDBOARD PLOWING	Clay Loam	Moist	12	68.1	5.68	14.0	- 5 x 400 mm plow - wheat stubble in old corn stalks.
	4	MOLDBOARD PLOWING	Clay Loam	Moist	34	195.2	5.74	14.2	- wheat stubble - 150-180 mm deep.
	4	MOLDBOARD PLOWING	Clay Loam	Moist	89.5	572	6.39	15.8	- corn stalks - 150-180 mm deep.
				AVERAGE OF 3 OBSERVATIONS			5.94	14.7	- near ideal plowing conditions.

FIELD FUEL USE - DATA SUMMARY

I-1

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
	1	CHISEL PLOW	Clay Loam	Wet	65	353	5.43	13.4	- 13 tooth unit - 150 mm deep - soybean stubble
	1	S-TINE CULTIVATE	Clay Loam	Moist	105	179	1.70	4.21	- 8.5 m wide - soybean stubble
	1	CHISEL PLOW AND S- TINE	Clay Loam	Moist	2 x 7	90	6.42	15.9	- as above - soybean stubble
	1	SPREAD FERT. AND CHISEL PLOW	Clay Loam	"	87	586	6.74	16.6	- soybean stubble
	1	CHISEL PLOW	Clay Loam	"	45	358	7.96	19.7	- soybean stubble - hard ground following tiling
	1	COULTER-CHISEL PLOW	Clay Loam	"	2 x 20	180	9.00	22.2	- two passes - corn stalks
	2	COULTER-CHISEL PLOW	Loam	"	180	1159	6.44	15.9	- one pass - corn stalks - floated by concave coulters
	4	S-TINE CULTIVATE	Clay Loam	"	75	191	2.54	6.29	- 6 m c/w rolling harrows - 130 mm deep - soybean stubble (1x for wheat)
	6	PLOW/PACK	Sand	Dry	16	116	7.28	18.0	- in spring - 130 to 150 mm deep - 3 x 400 mm plow
1987	4	CHISEL PLOW	Clay Loam	Dry	25	81.7	3.27	8.07	- 3 m chisel plow - pea stubble in July.
			AVERAGE	NOT	APPLICABLE				

FIELD FUEL USE - DATA SUMMARY

J-1

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
1	5	TANDEM DISC	Sand	Dry	50	147.7	2.95	7.30	- 4.3 m disc - 100 mm on fall mulched field
2	6	TANDEM DISC	Clay Loam	"	20	54.6	2.73	6.74	- 3 m disc - 130 to 150 mm deep
3	6	TANDEM DISC	Clay Loam	"	18	36.4	2.02	4.99	- 3 m disc - 100 mm deep
			AVERAGE	OF 3 OBSERVATIONS			2.57	6.34	
	4	HARROWING	Clay Loam	Dry	25	15.9	0.64	1.57	- 6 section (5.5m) diamond harrows

K-1

FIELD FUEL USE - DATA SUMMARY

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
1	1	COMBINING CORN	Clay Loam	Field Cap.	83	566	6.82	16.8	- 6 row narrow header - combine to truck
2	1	COMBINING CORN	Clay Loam	"	60	413	6.88	17.0	"
3	1	COMBINING CORN	Clay Loam	"	90	697	7.74	19.1	"
4	1	COMBINING CORN	Clay Loam	"	132	966	7.32	18.1	" - good ground conditions
5	3	COMBINING CORN	Clay Loam	"	44	334	7.59	18.8	- 2 row wide header - combine to truck - no rutting
6	2	COMBINING CORN	Loam	"	45	320	7.12	17.6	- 6 row narrow header - 75% grain buggy support - 10.6 h - 4.25 A/h avg.
7	2	COMBINING CORN	Loam	"	90	628	6.98	17.2	- 100% grain buggy support - 24.6 h - 3.66 A/h avg.
8	2	COMBINING CORN	Loam	"	100	692	6.92	17.1	- 50% grain buggy support - 27 h - 3.70 A/h avg.
			AVERAGE OF 8	OBSERVATIONS			7.17	17.7	

L-1

FIELD FUEL USE - DATA SUMMARY

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
1	3	COMBINING SOYBEANS	Clay Loam	Field Capacity	24	85.9	3.58	8.84	- 3 m header - no mud - no weeds
2	3	COMBINING SOYBEANS	Clay Loam	Wet	16.5	88.6	5.37	13.3	" - rutting 20% of field - had to back out
3	1	COMBINING SOYBEANS	Clay Loam	"	90	473	5.26	13.0	- 4.6 m header - wet spots (backing out) - no weeds
4	1	COMBINING SOYBEANS	Clay Loam	Field Capacity	80	328	4.10	10.1	" - no wet spots
5	1	COMBINING SOYBEANS	Clay Loam	"	90	430	4.78	11.8	"
			AVERAGE OF 5	OBSERVATIONS			4.62	11.4	
	1	COMBINING WHEAT	Clay Loam	Dry	55	209	3.80	9.40	- 4.6 m header - minimum straw throughput

FIELD FUEL USE - DATA SUMMARY

M-1

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
	6	IRRIGATION	Sand	---	7 h	75	10.7 L/h		- 45 kW tractor - pto pump - frost protection/tobacco
	3	DRILLING WINTER WHEAT	Clay Loam	Moist	47.4	37.9	0.80	1.97	- 21 x 7 drill with press wheels removed - drilling 12 to 20 mm deep
	3	DRILLING PEAS	Clay Loam	Dry	24.5	25.5	1.04	2.57	- 21 x 7 drill c/w press wheels - planting 60 mm deep

N-1

FIELD FUEL USE - DATA SUMMARY

OBS. #	COOP. #	FIELD OPERATION	SOIL TYPE	MOIST.	ACRES	DFE (L)	SPEC. FUEL CONS. L/A	L/ha	COMMENTS
1	4	FORAGE HARVESTER	Clay Loam	Wet		14.4 L/h	14.4	35.6	- 1 row harvester - very muddy conditions - one acre per hour
	4	WAGONS TO SILO	Gravel Road	---		2.55 L/h	2.55	6.30	- short haul (1/2 km) - tractor running continuously to unload
	4	BLOWER TRACTOR	----	---		4.55 L/h	4.55	11.24	- four loads per hour - tractor idling between loads
									* Loads were small due to very wet field conditions (Fall '86)
		Note: This information is preliminary and should not be used as representative.							
1987	4	CORN SILAGE	Clay Loam	Dry	25	613	24.5	60.0	- 3 tractors - 6 x 18 m silo
									- 1 row harvester - short haul (1/2 Km)
									- 495 t (estimate) - thus 1.24 L/t